Chapter 24
Organic Amendments and Soil Suppressiveness: Results with Vegetable and Ornamental Crops

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24.1 Introduction

Vegetable and ornamental crops are high-value production systems, economically important worldwide, facing severe limitations in the use of chemicals and continuous innovations and adaptations to climate change and new diseases. Many new crops and varieties were introduced in the last decades, together with changes in the horticultural industry and in the food market. Potted plants are partially replacing cut aromatic and ornamental plants, while new products such as ready-to-eat processed salads are requesting improved growing techniques and new production areas. Rapid changes in the production systems are influencing disease development and their management. Together with the phase-out of methyl bromide and the regulatory constraints for the use of soil fumigants, growers are facing also new diseases as a consequence of the introduction of new cultivars and crops and the intensification of the production systems.

This review will focus on the use of organic amendments, compost in particular, and soil suppressiveness for the management of diseases of vegetable and ornamental crops.

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24.2 Soil Suppressiveness and Organic Amendments

Soil suppressiveness is considered a complex system in which soil, microflora and plants play the main role. Suppressive soils or substrates are those in which the disease development is naturally controlled, even in the presence of a virulent pathogen, a susceptible plant host, and with good environmental conditions for the development of the disease. Both biotic and abiotic elements are considered to be important for the suppression of plant diseases, but the microbial activity is considered as a key element. All natural soils have a general disease suppression compared to the same pasteurised soil, and it is directly related to the amount of microbial activity. In cropping systems, due to soil cultivation and management, a specific suppression is concerned, where an individual or group of microorganisms, selected for their antagonistic activity, is directly responsible for disease suppression.

The application of organic amendments is a strategy commonly used in traditional agricultural systems for providing nutrients to the crops and for improving soil fertility. Several chemical and biological changes in the soil are associated with the incorporation of amendments and correlated to the control of soilborne diseases, with a good potential for their management thus reducing chemical inputs (Bailey and Lazarovits 2003; Bonanomi et al. 2007; Bonilla et al. 2012). However, a widespread use of organic amendments for disease control is still not being achieved, due to many factors such as the type of amendments, the lack of standardisation, the inconsistency in their efficacy and the complexity in their use. In most cases, the application rates effective under controlled conditions are too high for field crops; in others prior crop management practices do not allow a proper use of amendments. A gap between good results observed in laboratory and greenhouse compared to few promising results in the field is still relevant today, as mechanisms of action are largely unknown and risk avoidance is too much limited compared to other disease control strategies. Some studies indicate that the effectiveness of organic amendments is variable and, in some cases, can enhance severity of some diseases (Mazzola 2007). Organic amendments include manure, crop and food residues, compost, organic fertilisers, etc. Their use can help to control soilborne pathogens in vegetable and ornamental crops, especially when applied in conjunction with other management practices and considering a system approach. The aim is to maintain the soil's stability and resilience and to promote a self-regulation and self-balance of the agro-ecosystem. Such an approach is very interesting in the case of organic farming, where the use of amendments, in combination with mulching and other cultural practices, is effective against many soilborne pathogens.

Amendments can be applied together with other methods, like soil solarisation, anaerobic soil disinfestation and soil fumigations, to reduce the density of pathogens. When added to soil, amendments such as cow or poultry manure and cruciferous residues are subjected to microbial degradation that results in the generation of both toxic and volatile compounds directly affecting soilborne pathogens propagules or indirectly increasing microbial antagonistic activity in the soil. Positive effects of solarisation integrated with organic amendment have been observed for several soilborne fungi (*Rhizoctonia solani*, *Pythium* spp., *Fusarium oxysporum*, *Verticillium* spp., *Sclerotium rolfsii*), nematodes and also many weeds (Gamliel 2000; Mattner et al. 2008). However, released toxic compounds may result in phytotoxic effects on crops and some limitations to practical applications. In other cases they are applied and integrated with agronomical strategies, like the use of resistant grafted plants, in order to delay the root infections and provide additional times for the establishment of disease-suppressive microbial communities in the rhizosphere. The application of organic amendments can further promote the re-establishment of a more balanced and suppressive soil microflora, when combined with cultural practices like no-tillage and soil mulching. Furthermore, the development of plant disease is reduced thanks to the good root systems growing in a soil rich in organic matter and managed accurately (Chellemi 2010).

Among organic amendments, composts and *Brassica* pellets are considered those more promising. The use of *Brassica* species as green manure is considered a type of biofumigation that, involving the release of volatile compounds such as thiocyanates and nitriles, control multiple soilborne pathogens (Larkin and Griffin 2007; Handiseni et al. 2012). Studies carried out under greenhouse conditions showed improved control of *Colletotrichum coccodes* of tomato by mixing into the soil *Brassica carinata* dried pellets (Table 24.1; Gilardi et al. 2014a). The use of organic amendments, such as *B. juncea* green manure, provided a positive effect on eggplant grafted onto *Solanum torvum* partially resistant to *Verticillium dahliae* eggplant (Garibaldi et al. 2010). The combination of green manure with soil solarisation is also very effective and reduces the period of time for the soil covered with plastic films. Under simulated conditions of optimal and suboptimal temperature, it is possible to control Fusarium wilt of lettuce, rocket and basil with biofumigation, using *Brassica carinata* pellet, combined, respectively, with 7 and 14 days of soil solarisation (Garibaldi et al. 2010; Gilardi et al. 2014b). Field trials

Table 24.1 Incidence of *C. coccodes* expressed as percentage of infected roots on tomato cv. Arawak, grafted or not-grafted, in a naturally infested soil, with or without the addition of *Brassica* pellets, and the effect on yield [adapted from Gilardi et al. (2014a)]

Rootstocks	Biofumigation	Training system	% of roots affected by the attacks of *C. coccodes*		Total yield (g/plant)
–[a]	No	1 branch	35.9	C[b]	4837.7 a
Beaufort	Yes	1 branch	21.3	ab	6821.3 de
Beaufort	Yes	2 branches	23.4	abc	7051.5 de
Arnold	Yes	1 branch	14.1	a	6556.7 c
Arnold	Yes	2 branches	14.1	a	6915.4 d
–	Yes	1 branch	24.4	abc	4991.6 a

[a] Not-grafted Arawak plants served as control

[b] Means of the same column, followed by the same letter, do not significantly differ following Tukey's test ($P < 0.05$)

using Brassicaceae seed meal formulations demonstrated to be an effective tool for the management of apple tree replant diseases (Mazzola and Brown 2010). However, some studies indicate that the effectiveness of *Brassica* residues is variable and, in some cases, disease severity can be enhanced (Lu et al. 2010).

24.3 Compost

Compost is the material derived from the decomposition of organic material such as recycled plant waste, biosolids, fish or other organic materials. Composting is a process which turns biomass into compost with the use of oxygen and certain microorganisms. Increasing the opportunities to use compost in agriculture and in particular in horticulture as a (potting) substrate for plants would contribute to the recycling of wastes and to reducing the use of non-renewable fertilisers.

24.3.1 Compost Quality and Use in Agriculture

Quality aspects of compost are of most importance in order to assure a proper use in agriculture. Compost quality refers to the overall state of the material with regard to physical, chemical and biological characteristics. These parameters are indicators of the ultimate impact of the compost on the environment. In particular, the most important parameters from the point of view of environment protection standards, public health and the soil are those related to pathogens, inorganic and organic potentially toxic compounds (heavy metals) and stability. Within the EU, standards on the use and quality of compost exist in most Member States, while there is not yet a comprehensive European Community legislation. Moreover, common analysis is not enough to assess compost quality according to specific uses, such as for potting mixes, vegetable and ornamental crops, soil-less systems and suppressing plant diseases. Consequently, it is important to define and use also agronomical tests to assess compost quality, and compost suppressiveness to plant pathogens is also a key point for high-quality compost to be taken into consideration.

Farmers' willingness to use compost is strictly connected to various quality aspects of compost. Compost is commonly used as a soil amendment to increase organic matter content and fertility by improving physical, chemical and biological soil conditions (Hoitink and Fahy 1986). The nutritive value of composts and their potential to enhance soil quality makes them ideal for agriculture but may unnecessarily increase the heavy metal content of the soil when applied at high dosages (Ramos and López-Acevedo 2004). Composts have the advantage to significantly increase soil organic matter (SOM) contents, a key soil quality indicator that is on the contrary declining in many regions of the world (Bellamy et al. 2005). Additional benefits of compost addition to soil are promotion of soil biological activity, reduction of erosion losses, decrease of bulk density, improvement of structural stability, nutrient availability and plant uptake and increase of water holding capacity (Shiralipour et al. 1992; Tejada and Gonzalez 2007). Crop growth or yield is usually increased by compost amendments in the field. Compost is also interesting as a peat substitute, in particular after recent increasing concern of the environmental impact of peat extraction and the damage of peat lands and natural habitats by the horticulture industry that lead to the adoption of alternative substrates (Silva et al. 2007). Also in field horticulture, there are great market opportunities for compost, although its use on leafy vegetables is unlikely due to the potential for microbiological contamination by human pathogens, especially in the case of municipal solid waste compost (Farrell and Jones 2009).

24.3.2 Compost Suppressiveness

The use of compost as a peat substitute to control root pathogens in Italy was first suggested in 1988 (Garibaldi 1988). The suppressive capacity of compost against soilborne pathogens has been demonstrated in several studies, and, consequently, the use of disease-suppressive compost can reduce crop losses caused by soilborne diseases and benefit growers (Hoitink and Fahy 1986; Hoitink and Boehm 1999; Noble and Coventry 2005; Pugliese et al. 2007; Hadar 2011). Compost showed to be the most suppressive material, with more than 50 % of cases showing effective disease control, compared to other amendments such as crop residues and peat (Bonanomi et al. 2007). In field trials compost showed, in most experiments, to be suppressive with an application rate of at least 15 tons/ha. Compost prepared from cannery wastes was able to suppress anthracnose caused by *Colletotrichum coccodes* and bacterial spot caused by *Xanthomonas campestris* pv. *vesicatoria* on tomato in soil (Abbasi et al. 2002). Lower applications, like 4 tons/ha, have also been reported to be sufficient for reducing dry root rot of bean caused by *Macrophomina phaseolina* (Lodha et al. 2002). In other cases, repetition for five consecutive years of compost at 10 tons/ha was necessary to suppress damping off of cucumber and lettuce caused by *Pythium ultimum* and *Rhizoctonia solani* (Fuchs 1995). Suppressive effect of compost is generally proportional to the inclusion rate in soil, like in the case of damping off of cress by *P. ultimum* and wilt of flax by *Fusarium oxysporum* f. sp. *lini* (Fuchs 1995; Serra-Wittling et al. 1996), but not always. Application of compost suppressed root rot of chile peppers caused by *Phytophthora capsici* when applied at 48 tons/ha but at higher rates (72 tons/ha), promoted the disease, probably by increasing soil salinity (Dickerson 1999), and suppressed damping off caused by *R. solani*. However, disease promotion of root rot of bean caused by *R. solani* on soil amended with dairy manure compost has also been observed (Voland and Epstein 1994). In the case of vascular diseases caused by *Fusarium* species and root rots and damping off caused by *Pythium* species, amending soil with compost generally suppressed or did not affect the diseases (Noble and Coventry 2005). Different results can be obtained by different composts on the same pathosystem. For example, verticillium wilt of potato caused by

V. dahliae was promoted by dairy manure compost but suppressed by vegetable waste compost (Noble 2011). Soil type and conditions, like texture, pH and moisture, can also influence suppressiveness to soilborne pathogens (Bruehl 1975). Coventry et al. (2005) found that vegetable waste compost was ineffective against *Sclerotium cepivorum* in a silt soil but suppressive on the same pathogen, causal agent of *Allium* white rot, in sandy loam and peat soils.

In container experiments using soil or sand, compost derived from green wastes and/or dairy cow manure generally showed a suppressive effect on *Pythium* species and *Rhizoctonia solani*, but results did not necessarily translate into the field (Noble and Coventry 2005). Compost equally suppressed white rot of onion caused by *Sclerotium cepivorum* in pot tests and in the field (Coventry et al. 2005). In other experiments composts suppressing *Phytophthora* on citrus seedlings in pot experiments were ineffective in field trials with the same soils (Widmer et al. 1998). Compost suppressiveness also showed to be dependent on the type of wastes used for preparation. For example, bark compost suppressed *Pythium* root rot, while grape marc showed neutral or promoting effects to disease (Erhart et al. 1999), and vermicomposted animal manure suppressed infection of tomato seedlings caused by *Phytophthora nicotianae*, but not root and stem rot of cucumber caused by *Fusarium oxysporum* f. sp. *radicis-cucumerinum* (Kannangara et al. 2000; Szczech and Smolinska 2001).

Low rates of compost in growing media are generally indicated, in order to avoid negative growth effects and phytotoxicity caused by high pH and electrical conductivity and other phytotoxic compounds present in composts (Sullivan and Miller 2001). However, it is generally necessary to include at least 20 % v/v of compost in containers in order to observe a suppressive effect. Lower rates are successfully applied for few specific cases, like *Ralstonia solanacearum* and *Rhizoctonia solani* (Voland and Epstein 1994; Islam and Toyota 2004). Cases of increase of disease severity caused by composts used in containers have also been reported. A 50 % spruce bark compost increased black root rot caused by *Thielaviopsis basicola* in poinsettias and Fusarium wilt of cyclamen, compared to a peat substrate (Krebs 1990). Highly saline composts were reported to enhance *Pythium* and *Phytophthora* diseases, while composts with higher nitrogen or ammonium content enhance Fusarium wilts (Hoitink et al. 2001). Among soilborne pathogens, *Rhizoctonia solani* is considered to be the most difficult one to be controlled with compost (Scheuerell et al. 2005; Bonanomi et al. 2007). Variability also depends on the pathosystem. A compost from wood chips and horse manure stimulated disease caused by *Rhizoctonia solani* on cauliflower but suppressed it on pine (Termorshuizen et al. 2006). Success or failure of compost for disease control depends on the nature of the raw materials from which the compost was prepared, on the composting process used and on the maturity and quality of the compost (Termorshuizen et al. 2006). Composting temperatures are important also for the eradication of plant pathogens and nematodes and the sanitisation of compost (Noble and Roberts, 2004). Fortifying composts with beneficial microorganisms is one possible factor that can help in the success of compost, increasing the efficacy and reliability of disease control (De Clercq et al. 2004).

24.3.3 Mechanisms of Action of Disease Suppression

Disease suppressiveness depends on soil or substrate properties, including both abiotic and biotic parameters (Mazzola 2004; Janvier et al. 2007). Regarding the influence of physicochemical properties of suppressive soils and substrates towards diseases, soils with higher pH showed to be more suppressive towards Fusarium wilts (Höper et al. 1995) but conducive for nematodes (Rimé et al. 2003). Acidic pH reduce incidence of potato scab caused by *Streptomyces scabies* (Lacey and Wilson 2001) or enhance suppression of take-all of wheat with *Trichoderma koningii* (Duffy et al. 1997). Concerning the N content of soil, a positive association was found on the suppressiveness towards *Pseudomonas syringae* on bean and cucumber (Rotenberg et al. 2005), *Fusarium* spp. on asparagus (Hamel et al. 2005), *Gaeumanomyces graminis* var. *tritici* and *Rhizoctonia solani* on wheat (Pankhurst et al. 2002) and ectoparasitic nematodes (Rimé et al. 2003). The form of N, either NO_3 or NH_4, is also important (Janvier et al. 2007), and NH_3 or HNO_2 showed to be able to kill microsclerotia of *Verticillium dahliae* in several soils (Tenuta and Lazarovits 2004). Higher C content showed to reduce incidence of *Pythium* damping off of tomato and *Fusarium solani* f. sp. *pisi* on pea and *Fusarium culmorum* on barley but to positively affect *Thielaviopsis basicola* (Oyarzun et al. 1998; van Bruggen and Semenov 1999; Rasmussen et al. 2002).

Other physicochemical characteristics are also important, like soil texture, cations and oligoelements. Suppressiveness to Fusarium wilts of flax and Armillaria root disease on lodgepole pine was found to be reduced in sandy soils (Höper et al. 1995; Mallett and Maynard 1998). Higher clay content was associated with less *Gaeumanomyces graminis* var. *tritici* on wheat after treatment with *Trichoderma koningii* (Duffy et al. 1997). No correlation on Fusarium wilt of banana (Dominguez et al. 2001) and *Fusarium* root rot of asparagus (Hamel et al. 2005) were found between soil texture and suppressiveness instead. Higher levels of Mg and K were found to reduce incidence of fungal disease (Duffy et al. 1997; Peng et al. 1999) and suppressiveness of nematodes (Rimé et al. 2003), providing contrasting results depending on the pathogen. Al, Fe, Na or Zn contents generally reduced disease levels (Oyarzun et al. 1998). After analysing 28 physical and chemical properties of ten soils, Ownley et al. (2003) found that 16 soil properties were correlated with disease suppression and proposed a model including six key soil properties ($N–NO_3$, CEC, Fe, % silt, soil pH and zinc) to explain the variance in take-all disease of wheat treated with phenazine-producing *Pseudomonas fluorescens*. In the case of suppressive composts, higher rates of CaO, MgO, K_2O and $N–NH_4$ and a higher CEC showed to suppress *Rhizoctonia solani* more than the control soil (Pérez-Piqueres et al. 2006). A loss in the disease-suppressive effect of composts following sterilisation or heat treatments has been demonstrated in several papers (Hoitink et al. 1997; Cotxarrera et al. 2002; Reuveni et al. 2002; Chen and Nelson 2008; Pugliese et al. 2011). A declining of microbial activity after long periods of maturation and, consequently, a reduction of disease suppression have been also reported (Zmora-Nahum et al. 2008).

Also the use of water extracts from composts showed to suppress several soilborne pathogens (El-Masry et al. 2002), indicating a predominant biological component rather than chemical or physical in the suppressive effect. Compost acts as a food source and shelter for the antagonists that compete with plant pathogens or parasitise them, for those beneficials that produce antibiotics and for those microorganisms that induce resistance in plants: high-quality compost should contain disease-suppressive microorganisms (Noble and Coventry 2005; Hadar 2011).

According to Hoitink and Boehm (1999), the following biological mechanisms are involved in compost suppressiveness:

(a) Competition for nutrients by beneficial microorganisms
(b) Parasitism against pathogens by beneficial microorganisms
(c) Antibiotic production by beneficial microorganisms
(d) Activation of disease-resistance genes in plants by microorganisms (induced systemic resistance)
(e) Improved plant nutrition and vigour, leading to enhanced disease resistance

The mode of actions (a), (d) and (e) generally occurs when disease suppressiveness is not accompanied by a reduction in soilborne pathogen inoculums (Lumsden et al. 1983; Lievens et al. 2001).

Bacteria belonging to genera *Bacillus* spp., *Enterobacter* spp., *Pseudomonas* spp., *Streptomyces* spp., *Penicillium* spp. as well as several *Trichoderma* spp. isolates and other fungi have been identified as biocontrol agents (BCAs) in compost-amended substrates (Chen et al. 1987; Boehm et al. 1993; Hoitink et al. 1997; Boulter et al. 2002; Pugliese et al. 2008). The isolation from roots of eggplants grown in compost of strains of *Pseudomonas fluorescens* and of *Fusarium oxysporum* controlling Verticillium wilt and the presence of microbial species that interact at rhizosphere level and suppress the disease of plants germinated in compost indicate that suppression is related to microorganisms, rather than to the growing substrate (Malandraki et al. 2007; Chen and Nelson 2008). Microorganisms, selected from a compost suppressive against Fusarium wilts, controlled *Fusarium oxysporum* and few other soilborne diseases like *Phytophthora nicotianae* and *Rhizoctonia solani* (Table 24.2; Pugliese et al. 2008). The addition of such microorganisms and BCAs might be considered a good strategy to increase compost suppressiveness and to partially restore disease suppressiveness of steam-sterilised compost (Table 24.3; Pugliese et al. 2011).

The presence of toxic or volatile compounds in compost, sometimes correlated with changes to the physical properties of the growing medium or soil or to soil pH and conductivity, is another possible mechanism (Noble 2011), suggesting compost use as alternative to chemical fumigants for managing soilborne pathogens, also integrated with soil solarisation (Katan 2000). Immature composts release volatile compounds containing sulphur, organic acids and ammonia that may be responsible for disease suppression (Scheuerell et al. 2005; Coventry et al. 2006). Phytotoxic compounds produced by soil microorganisms after application of farmyard

Table 24.2 Activity of microorganisms isolated from a suppressive compost against soilborne pathogens [adapted from Pugliese et al. (2008)]

Microorganism	Pathogen	% of disease control		
		F. oxysporum f. sp. *basilici*/basil	*Phytophthora nicotianae*/tomato	*Rhizoctonia solani*/bean
K5	Yes	69 ab[a]	28 bc	13 cd
K6	Yes	56 abc	0 c	15 cd
K7	Yes	64 ab	0 c	22 bc
E12	Yes	0 c	25 bc	14 cd
E15	Yes	0 c	31 bc	1 d
E19	Yes	10 bc	0 c	49 b
B3	Yes	16 bc	73 a	11 cd
B17	Yes	10 bc	82 a	29 bc
–	Yes	0 c	0 c	0 d
–	No	100 a	100 a	100 a

[a] Tukey's HSD test ($P < 0.05$)

Table 24.3 Effect of *Trichoderma* spp. added to a substrate made by compost and peat on the suppression of *Rhizoctonia solani* on bean [adapted from Pugliese et al. (2011)]

Substrate mix (% v/v)		Antagonist (dosage)	Pathogen	Disease suppressiveness (%)[a]	Biomass (%)[a]
Compost	Peat				
40	60	*T. harzianum* T-22 (4 g l^{-1})	Yes	40 b[b]	92 a
40	60	*T. viride* TV1 (4 g l^{-1})	Yes	−59 d	60 bc
40	60	*T. harzianum* ICC012 + *T. viride* ICC080 (2 g l^{-1})	Yes	−33 cd	53 c
40	60	Inoculated control	Yes	−46 d	63 bc
40	60	Control	No	100 a	115 a
0	100	Inoculated control	Yes	0[c] c	75[c] bc
0	100	Control	No	100 a	100 a

[a] Values represent the means of at least two bioassays

[b] Different letters represent significant differences between treatments according to Tukey's HSD test ($P < 0.05$). Negative figures indicate significant disease aggravation as compared to peat control

[c] The level of disease and biomass in the peat control is, respectively, 52 % of alive plants and 27.75 g

compost were found to suppress apple replant diseases (Gur et al. 1998). Investigating a wide range of biological and chemical characteristics of composts and compost-peat mixtures in relation to plant disease suppression, Termorshuizen et al. (2006) demonstrated that only pH increase resulting from compost amendment showed a consistent relationship with the suppression of some diseases, such as *Fusarium oxysporum*, but that there is no single factor conferring suppressiveness to composts.

Several approaches were used to monitor compost suppressiveness, microbial activity and related effects after organic amendment application to soil and substrates, including analysis of phospholipid fatty acids (PLFAs), enzymatic activities and DNA-based techniques (Noble and Coventry 2005). Overall, enzymatic and microbiological parameters, rather than chemical ones, are considered much more informative for predicting suppressiveness (Bonanomi et al. 2010).

Hydrolysis of fluorescein diacetate (FDA) and dehydrogenase activity have been suggested as indicators for damping off and root rot diseases (Chen et al. 1988; Scheuerell et al. 2005; Giotis et al. 2009), but the technique has not been found to be consistently reliable for predicting compost suppressiveness in other pathosystems (Erhart et al. 1999; Termorshuizen et al. 2006; Rotenberg et al. 2007). Factors like microbial community composition, decomposition time, amendment quality and pathosystem tested may interact with each other and make it difficult to identify specific indicators for disease suppression. According to Bonanomi et al. (2010), the response of pathogen populations is a reliable feature only for pathogens with a limited saprophytic ability (e.g. *Thielaviopsis basicola* and *Verticillium dahliae*) and for some organic matter types (e.g. crop residues and organic wastes with C/N lower than 15). The most useful parameters to predict disease suppression were FDA activity, substrate respiration, microbial biomass, total culturable bacteria, fluorescent pseudomonads and *Trichoderma* populations. Specific indicators have been indicated only for some pathogens. For instance, suppressiveness in peat substrate amended with compost may be predicted by total extractable carbon, *O*-aryl C and C/N ratio for *Pythium ultimum*; by alkyl/*O*-alkyl ratio, *N*-acetyl-glucosaminidase and chitobiosidase enzymatic activities for *Rhizoctonia solani*; and by electrical conductivity for *Sclerotinia minor* (Pane et al. 2011). DNA-based techniques such as analysis of terminal restriction fragment length polymorphisms (T-RFLPs) and denaturing gradient gel electrophoresis (DGGE) showed correlations between microbial diversity of compost-amended substrates and their suppressiveness to bean root rot, cucumber root rot caused by *Pythium aphanidermatum* and southern blight caused by *Sclerotium rolfsii* (Postma et al. 2005; Liu et al. 2007; Rotenberg et al. 2007).

24.4 Conclusions

Control of soilborne diseases with organic amendments must be viewed not as a stand-alone management approach but rather part of a system approach where several aspects of the impact of crop production practices on resident soil microbial communities are addressed. Organic amendments like *Brassica* manure are of particular interest for field crops, combined with soil solarisation, including fruit tree replant diseases, but not for other *Brassica* crops and vegetables like cabbage, cauliflower, broccoli, radish and wild rocket. Compost suppressiveness can be used both for potted plants and for field crops, combined with other management strategies like soil solarisation and grafting. Induced resistance by compost has also been observed and consequently used for the control of other pathogens or pests. However, quality standards are required in order to avoid phytotoxicity effects on plants and reduce the variability in the control of diseases. New approaches to monitor how microbial community structures in soil change as a result of organic amendment may lead to a better understanding of which changes in microbial communities are responsible for conferring the disease-suppressive effects. This may eventually lead to improved and more reliable disease control resulting from organic amendment of soil, sand or peat, both in container crops in greenhouses and in the field.

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